Thermal Conversion R&D

Converting IES Waste Heat into Heating and Cooling Work

IES Program Review
April 30 – May 2, 2002

Steve Slayzak
Project Manager
Center for Buildings and Thermal Systems
National Renewable Energy Laboratory
steve_slayzak@nrel.gov

Overview

- **Background – Thermal Conversion R&D**

  Summary of NREL's Thermal Conversion R&D and the role of desiccant systems as a core IES technology

- **Liquid Desiccant Systems for Anthrax Protection in High Risk Buildings**

  R&D effort to apply liquid desiccant systems to Homeland Security.

NREL Team Capabilities

Dick DeBlasio – DER Program Manager

Ren Anderson – Buildings Program Manager

Steve Slayzak – Thermal Conversion Proj. Manager

Joe Ryan – Thermal Conversion R&D

Ali Jalalzadeh-Azar – Thermal Conversion Analysis

Ed Wolfrum – Contaminant Sensors and Analysis

Ahmad Pesaran – Desiccant Technology

Dan Blake – Contaminant Chemistry

Desikan Bharathan – Advanced Aerosol Capture

Todd Vinzant – Microbiology

Doug Powell – Master Technician

Judy Netter – Master Technician

NREL Thermal Conversion Research

- In order to give distributed power an energy advantage, our goal is to develop highly efficient thermally driven heat and mass transfer components for IES that convert waste heat into heating/cooling work with cost, durability, and performance in line with market expectations:
  - Thermal COP: 1+
  - Cost: $1.25/cfm
  - Heat Recovery Efficiency: 0.8+
  - Significantly increase Indoor Environmental Quality (IEQ)

Desiccants: A Core IES Technology

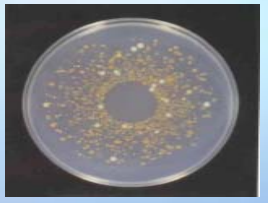
- The DER Program is developing solid and liquid desiccant technology to
  - Recover thermal energy from building exhaust air
  - Pre-condition building ventilation air
  - Recover waste heat from onsite power generation
- In addition to reducing energy use, desiccant technology improves IEQ
  - Allows increased ventilation rates
  - Controls indoor humidity and reduces potential for mold and mildew growth
  - Removes airborne contaminants

Desiccant Component Energy Benefits

- Latent (moisture) loads account for about 30% of overall building cooling loads
- Heat recovery wheels can recover 80% of energy from building exhaust air and onsite power waste heat streams
- Desiccant components can reduce peak loads and AC equipment sizing requirements

Moisture Problems in Buildings

DUST MITES



BACTERIA

FUNGUS

MOLD DAMAGE

CORROSION

Industry Partnerships

- **Current Contracts**
  - AIL Research, CDH Energy, Dais Analytic, Drykor, Kathabar, Rotor Source, and U. of Illinois Chicago Energy Resource Center
- **Collaborative R&D**
  - ARI, Air Technology Systems, AirXchange, American Gas Cooling Center, ASHRAE, HeatCraft, Honeywell, Intertech Testing Services, Munters Cargocaire, Nautica, NCI Mfg., NETL, NovelAire, ORNL, SEMCO

NREL Advanced HVAC Test Facility

Thermal Conversion Test Facility

DER Lab Network

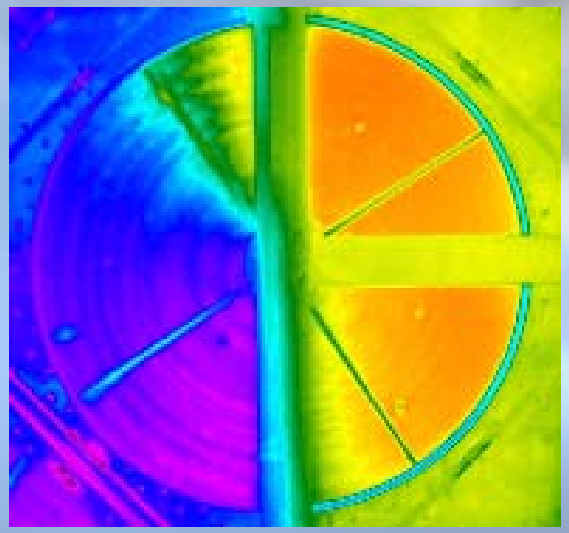
Thermal Conversion Facility Test Capabilities

- High Accuracy Testing
  - Dehumidification Capacity: ± 5%
  - Heat recovery effectiveness: ± 3%
  - Moisture recovery effectiveness: ± 5%
- State-of-the-Art Data Rate
- Broad Range of Test Conditions in Four Independently Controlled Airstreams
  - Air flowrates: 30 - 6000 scfm
  - Temperatures: 30 - 400°F
  - Humidities: 20 - 250 grains/lb
- Tight Set-point Tolerances
  - Dry-bulb: ± 0.3°F
  - Dew-point: ± 0.3°F

DER DISTRIBUTED ENERGY RESOURCES

NREL

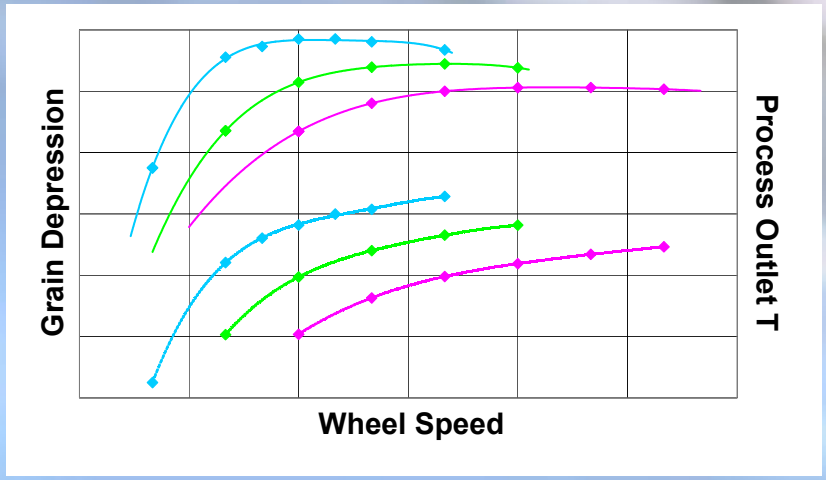
Thermal Conversion Facility
Advanced Diagnostic R&D Capabilities

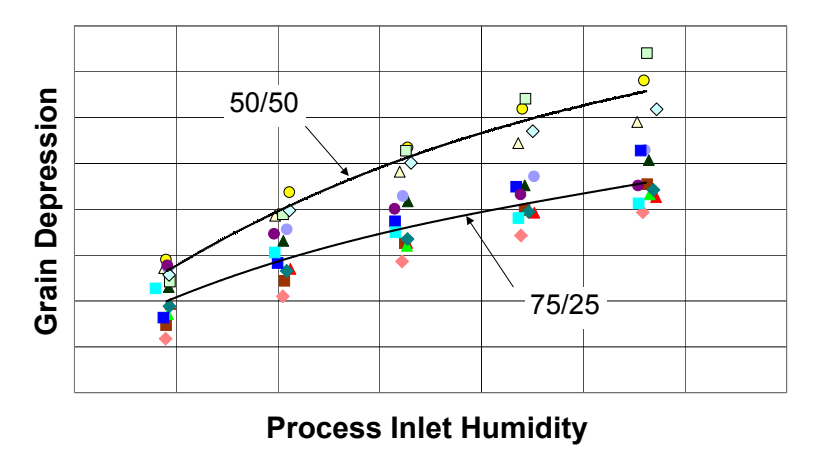


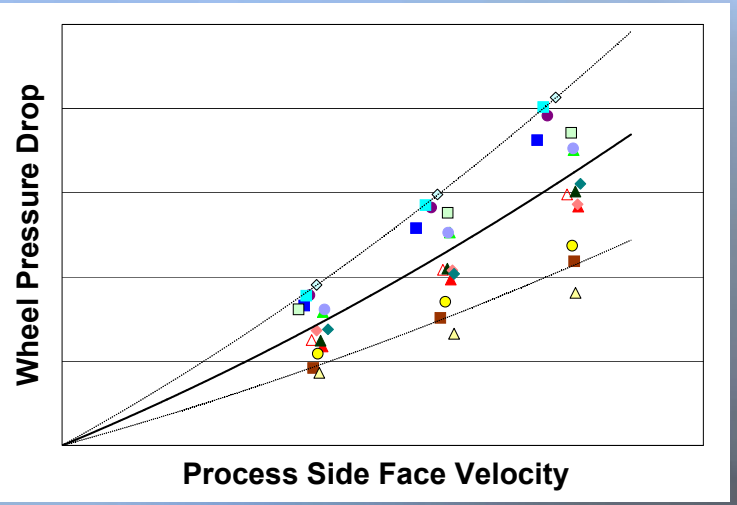
- Infrared Imaging
  - Matrix uniformity
  - Loading uniformity
- Tracer Gas Leak Measurement
- Accelerated Contaminant Removal Testing
  - Industrial – ppm level
  - Indoor Air – ppb level

Solid Desiccant R&D

- Broad dehumidification performance maps, energy-efficiency, pressure drops, speed optimization, etc.
- Facilitated 10%-60% increase in enthalpy wheel latent effectiveness







Liquid Desiccant R&D

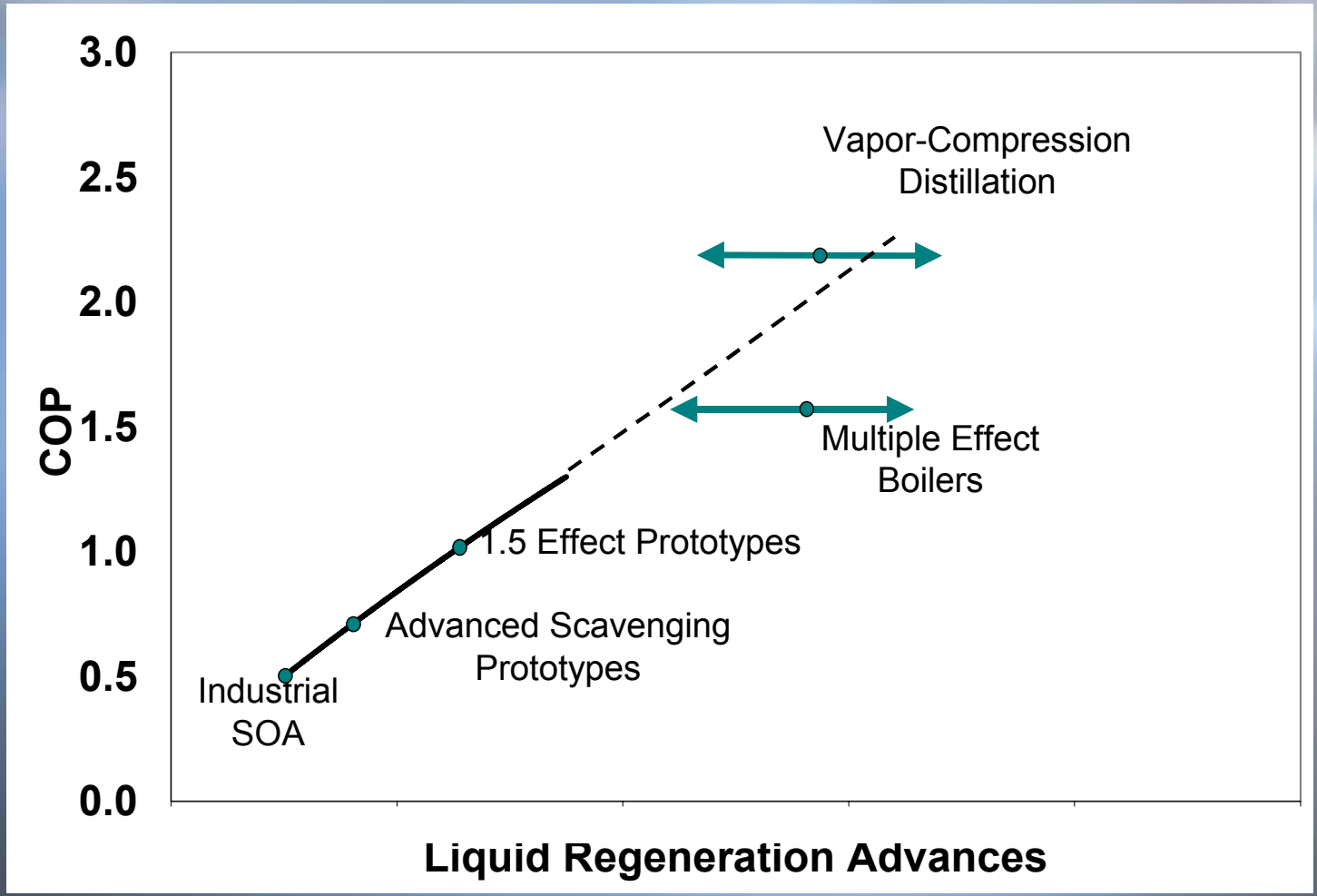
- Produced conditioner superior in size, cost, performance, and maintenance to SOA
- Excellent for IES
  - Low temperature regeneration
  - Distributed conditioning – centralized regeneration
- Biocidal air-cleaning capability

AIL Research, Inc.

DER DISTRIBUTED ENERGY RESOURCES

NREL

Liquid Desiccant EE R&D Path



Thermal Conversion R&D Topics

Five publications, over two-dozen technical briefs, and a summary report on over a dozen wheels covering:

- CHP analysis for commercial loads
- Tracer gas seal testing techniques
- Waste heat storage optimization analysis
- Wheel speed optimization: enthalpy and DH applications
- Enhanced durability materials
- Flooding/transfer rate optimizations for absorbers
- Latent capacity in sensible wheels
- Wheel face split tradeoffs
- Regeneration energy modulation tradeoffs
- Regeneration temperature/waste heat tradeoffs
- Desiccant masking
- Desiccant staging

Thermal Conversion R&D Accomplishments

- Precipitated a 10%-60% increase in enthalpy wheel latent performance nationwide through round-robin testing with ARI
- Validated protocols for extending desiccant device test results to all altitudes
- Desiccant staging evaluations show promise
- Evaluations of cooling-based dehumidifiers show good efficiency, poor performance
  - Grain depression < 30 and T_{PO} ~ 100F

Thermal Conversion Project Accomplishments

- Enhancements to the Thermal Conversion Test Facility providing side-by-side test capability, increased accuracy, data rate, and equipment capacity.
- National recognition for technical leadership. Project leader installed as chairman of ASHRAE TC 3.5 - Desiccant and Sorption Technology.
- Researcher exchanges with manufacturers have significantly improved in-house testing capabilities nationwide.

FY'02 Project Plans

- Shakedown testing of our facility upgrades
- Evaluations of advances in:
  - liquid desiccant regeneration
  - new high performance and low-cost wheels
  - high performance moisture exchange membranes
- Field tests to provide:
  - packaged absorber core performance
  - detailed data to enhance analyses for IES waste heat conversion
- R&D and partnerships to apply liquid desiccant air washing abilities to indoor environmental security
  - aerosol capture
  - agent inactivation

A New Challenge for Liquid Desiccants: Indoor Environmental Security

Appropriate Technical Responses to Terrorism

- Dilemma of rare occurrences with high consequences
- Explain what is and is not technically possible for defense
- Dual-use systems that provide a primary, 24/7 benefit in addition to a security function
- Systems that expedite recovery of facilities damaged by attack

Desiccant Benefits for Homeland Security

- The air cleaning benefits provided by liquid desiccant systems can be optimized to control the spread of aerosol weapons.
- Liquid desiccant systems can play an important role as part of a comprehensive risk reduction strategy in anthrax and other airborne biological and chemical attacks.

Why Pursue Liquid Desiccants for IES?

- Weaponized particles can stay suspended in air for several hours after an attack, posing an exposure risk to unalerted occupants
- Conventional air handling systems can spread contamination throughout the building
- A liquid desiccant scrubber will lower concentration levels and exposure risk in the space and limit spread, facilitating subsequent decontamination efforts

Liquid Desiccant Unit at Integration Test Center

DER DISTRIBUTED ENERGY RESOURCES

NREL

Why Pursue Liquid Desiccants for IES?

- Cost-effective system based on existing industrial equipment
- Industrial air-washer systems proven to reduce colony-forming-units by > 94%
- Desiccant liquids proven to be stable for HVAC applications
- Liquid desiccant systems can be used to provide airborne contaminant removal and local air treatment as part of a comprehensive sterilization system for high risk building zones

DER DISTRIBUTED ENERGY RESOURCES

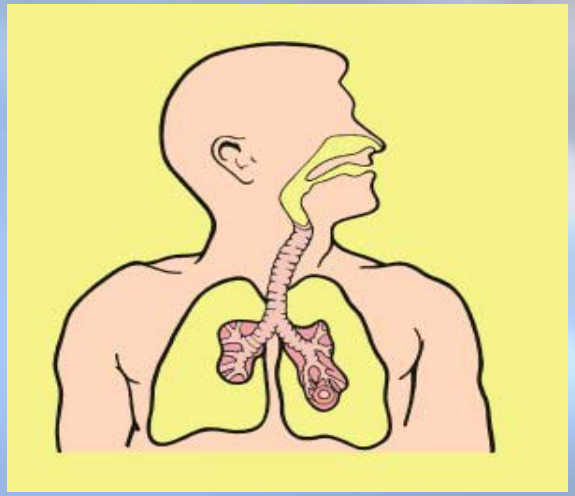
NREL

Why Pursue Liquid Desiccants for IEQ?

- Pathogens caught in air-washer cannot be shaken off and reintroduced into the building as with a filter
- Continuous agent destruction does not result in concentrated biohazard as with a filter

Capture Goal

- Develop an air-cleaning system capable of removing airborne spores in targeted applications with maximum security impact - fresh air supply and high-risk spaces like mailrooms
- Primary health risks are associated with respirable particles (1-5 microns)
- R&D is needed to optimize a hybrid collection device for the target particle range
- Single-pass capture efficiencies approaching 100% are possible at reasonable energy cost that would substantially reduce risk to building occupants



Methods for Spore Inactivation

- **Inactivation techniques fall into three categories:**
  - Chemical
    - **Ozone (O3), Bleach, Hydrogen Peroxide (H2O2), Ethylene Oxide**
  - Thermal
    - **Dry Heat, Steam**
    - **Autoclave sterilization is known to inactivate spores (250F for 15 minutes)**
  - Radiative
    - **UV light, X-rays, g-rays, b-radiation, electron beam**
- **Inactivation mechanisms include DNA crosslinking and oxidative membrane damage**

Questions